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NEW INVESTIGATION OF SHORT WINGS WITH LATERAL JETS

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16. Abstract

The work describes the lift of short wings by means of lateral fluid jets fired in the plane of the wing in the direction of the span. After some theoretical considerations, the experimental results obtained in a wind tunnel on a series of wings of various lengths are presented.

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NEW INVESTIGATION OF SHORT WINGS WITH LATERAL JETS

by
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Studii si Cercetari de Mecanica Aplicata, Vol. 29, No. 4, pp. 947-962 (1970)

The work involves the lift of short wings by means of lateral fluid jets fired in the plane of the wing in the direction of the span.

After some theoretical considerations, the experimental results obtained in a wind tunnel on a series of wings of various lengths are presented in the form of graphs.

The efficiency of the lift due to fluid longitudinal jets, that is, of jets fired from the edge of the wing in the direction of the flow from infinity (jet-flap), is considerably reduced when the length of the wing is decreased. In addition to increasing the efficiency of longitudinal jets, the simultaneous firing of some lateral fluid jets in the direction of the span possesses also a direct effect which is independent of that of longitudinal jets. In our previous studies [1, 3], we initiated a study of lateral jets, both in combination with longitudinal ones, and operating completely independently, examining their favorable effect in the latter case on a rectangular wing with a length of 2. However, we observed that this favorable effect is very large at short wings. Therefore, we studied lateral jets systematically, independently of the study of longitudinal ones, pointing out the efficiency of lateral jets on short wings. The same analytical study covered also lateral jets inclined by a certain angle with respect to the plane of the wing. The downward inclined jet has the effect of recovering partially its reaction in favor of the lift.

However, the present study involves exclusively lateral jets fired in the plane of the wing (in the direction of the span) for which we developed also a "theoretical model", in order to explain this interesting phenomenon from the scientific viewpoint.

1. Theoretical considerations

Let us consider a rectangular wing with a span of b and a chord c; at the head of the wing, in the direction of the span, let us consider a jet of the same depth as the chord, possessing the same incidence with respect to the wing at the exit (Figure 1).

At the beginning, the jet behaves as a plate in a uniform current, on the faces of which there is a distribution of pressures which yield the resultant C_{lx} on both faces at a certain point x, representing the local lift coefficient and causing the twisting of the plate, thereby modifying the incidence.

Let us consider the jet created from narrow strips dx (Figure 2). Each of the strips will have a local lift coefficient as a function of x, corresponding to its position on the chord; it can be put in the following form:

$$C_{lx} = f(x)\, C_{ly}, \qquad (1)$$

where C_{ly} is the mean value of the lift coefficient in a certain section y of the span; if we designate with Γ the circulation around this section, the latter will be derived from the equation

$$\rho U_\infty \Gamma = \frac{\rho}{2} U_\infty^2\, c C_{ly}. \qquad (2)$$

The elementary lift dP on an element ds of the arc of the strip dx will be

$$dP = \frac{\rho}{2} U_\infty^2\, C_{lx}\, dx\, ds = \frac{\rho}{2} U_\infty^2\, C_{lx}\, dx\, R\, d\theta, \qquad (3)$$

where R is the radius of curvature that the strip will obtain at a certain point x on the chord of the jet sheet from section y on the span.

Let us designate also with

$$I = \rho_j \delta_j U_j^2 \qquad (4)$$

the value of the pulse on the unit length of the jet where ρ_j is the density, δ_j is the thickness, and U_j is the speed of the fluid jet. In agreement with the pulse theorem, the radius of curvature of this strip is given by the relation

$$2I\,dx\frac{d\theta}{2}=\frac{\rho}{2}U_\infty^2 C_{lx}\,dx\,R d\theta, \tag{5}$$

from which we obtain

$$R=\frac{I}{\frac{\rho}{2}U_\infty^2 C_{lx}}=\frac{I}{\frac{\rho}{2}U_\infty^2 f(x)\,C_{ly}}. \tag{6}$$

It results from this that each fluid strip from the jet will be curved in a different way along the chord; therefore, it will become uneven, leading to a deformation of the jet in each of the sections, whereby the jet will have a different profile, with varying incidences along the chord.

On the jet sheet, we define a "mean line" representing the geometric locus of all points of application of the resultant of the pressures in each section y from the jet sheet. We designate the radius of curvature of this mean line by R_m.

It should be noted further that the overall lift on the jet sheet in a given section y is related to this radius of curvature by a relationship similar to (5):

$$2Ic\,\frac{d\theta}{2}=\frac{\rho}{2}U_\infty^2 C_{ly}\,c\,R_a\,d\theta=\rho U_\infty\Gamma R_m d\theta. \tag{7}$$

This situation is illustrated in Figure 4, which represents the photographic picture of the jet sheet. This radius of curvature is given by a formula similar to (6):

$$R_m=\frac{I}{\frac{\rho}{2}U_\infty^2 C_{ly}}=\frac{Ic}{\rho U_\infty\Gamma}. \tag{7'}$$

If we introduce further an adimensional jet coefficient:

$$C_j=\frac{Ic}{\frac{\rho}{2}U_\infty^2 c^2}=\frac{I}{\frac{\rho}{2}U_\infty^2 c}, \tag{8}$$

Formulas (6) and (7) above become respectively

$$R = \frac{cC_j}{f(x)\,C_{lv}}, \tag{9}$$

$$R_m = \frac{cC_j}{C_{lv}} = \frac{U_\infty c^2 C_j}{2\Gamma}. \tag{9'}$$

We can observe from Equation (9) that the transversal profile of the jet sheet assumes a complex geometric form; it is twisted and thereby a supplementary incidence which varies along the span according to a certain law, is introduced. This supplementary incidence is added to the initial incidence α_0 of the real wing, in such a way that if we designate the total incidence with α , we have on the fluid wing

$$\alpha = \alpha_0 + \varepsilon. \tag{10}$$

Actually, the phenomenon is very complex; it is complicated by the fact that on the one hand, by the interaction of the jet from infinity and the alteration of the flow conditions at the surface of the jet due to the viscosity, and on the other hand, to the excessive torsion of the jet sheet which offers a sufficiently large frontal surface to be reversed and thrown downstream according to laws which are difficult to determine. However, we can observe that at the extremity of the fluid wing, the jet sheet makes an approximately circular loop.

The above physical scheme indicates that the increased torsion of the jet results in a new increase of the incidence, and thus a new increase of the circulation on the wing. However, when the deformation on the jet sheet becomes excessive, the aerodynamic laws around the jet become complex and the concept of "incidence" does not have any sense.

The viscosity-induced thickening of the jet causes some of the particles from the jet to be carried by the current, thereby complicating the motion and transforming it into a chaotic one.

As far as the suction caused by the jet on the external curvature of the wing is concerned, it delays the phenomenon of the detachment of the air current on the profile, ensuring that the lift will follow the law of growth also for very large incidences.

This scheme of the solid and fluid wing can be integrated in Prandtl's theory of wings with finite span, and consists in the assimilation of the real wing extended by a fluid jet sheet with a solid fictive wing. However, this analogy is valid only up to a certain point of the span, after which the torsion becomes excessive, while the motion becomes complicated without reducing the circulation thereby. It is maintained further as an effect of the intensity of the fluid jet; the latter is twisted and wraps itself into a helicoidal form, being thrown downstream.

On the basis of the above considerations which attempt to clarify the complex phenomena involved in this problem, a theoretical model allowing to calculate the lift coefficient and the resistance of the solid wing can be developed.

We will consider these problems in other studies. In this article we present the remarkable experimental results that we obtained.

2. Experimental results

The experiments carried out in the wind tunnel of the Institute of Fluid Mechanics in 1968 are a continuation of tests undertaken many years previously [1, 2] in the same wind tunnel, on wings with a length of λ=2. The new experiments were carried out on short wings, specifically having a length of

$$\lambda = \frac{b}{c} = 2;\ 1{,}5;\ 1;\ 0{,}6$$

which showed indeed that the effect of the lateral jets on short wings is simply spectacular.

The profile of the tested wings was symmetrically biconvex.

At the head of the wing, a narrow slit along the chord (Figure 5) in the direction of the axis of the profile is connected by means of a duct to a compressor which ensures the air supply of the jet sheet.

The jet sheet is created in the plane of the wing in the direction of the span throughout the whole length of the chord. In order to obtain uniform distribution of the speed in the jet sheet, a series of baffles were displayed inside the wing on the air supply circuit from the compressor. The intensity of the jet and that of the pulse coefficient were varied by varying the air supply from the compressor.

The model was mounted in a vertical position on a disk attached to an aerodynamic balance which could be rotated around an axis parallel with the span in order to change the incidence with respect to the air current from the wind tunnel.

In order to avoid a rigid connection between the wing mounted on the balance and the air supply duct from the compressor, a flexible connection through a mercury container was provided, in order to ensure good leak tightness and to avoid introducing the action of external forces on the model. A vertical glass tube communicating with this mercury container was used as a manometer in order to determine the air pressure in the supply duct from the compressor.

The aerodynamic forces acting on the model were determined by tensometric methods, measuring the deformations which appear in an elastic element mounted in such a way that it was stressed by a single component of the aerodynamic force.

The deformation-sensitive electric transducers were connected with the plastic element to form a measurement circuit. Preliminary calibration helped to establish the proportional relationship between force and deformation.

The interior of the metalic model was provided with air supply ducts for the jet. In view of the large number of parameters which must be taken into account in the experiments, the following method was adopted: the incidence of the wing was kept constant, changing the jet coefficient from 0 to a maximum value limited by the functional characteristics of the installation in question. The variation of the lift coefficient as a function of the jet coefficient C_j for a given value of the incidence was thus obtained. These experiments were repeated for various wing incidence values, obtaining a diagram for each of the incidences. These diagrams are shown in Figures 7-10 for wing lengths of λ =2, 1.5, and 0.6.

With the help of these diagrams, we determined the values of the lift coefficients of the wing, i.e. C_l, for a given value of the jet coefficient C_j as a function of the incidence α_o which made it possible to plot the curves C_l as a function of the incidence α_o of the wing.

These curves were plotted in Figures 11-14 for the same length values and for jet coefficient values of C_j = 0.25, 0.50, 0.75, and 1. Study of these diagrams revealed that for short lengths, lateral jets increase considerably the lift coefficient.

In order to illustrate this, we determined the ratio of the lift coefficient of the wing with a lateral jet, designated as C_{lj}, and the lift coefficient of the wing without jet, designated as C_{lo}; i.e.

$$C_{ij}/C_{lo}$$

The diagrams shown in Figures 15 to 18 represent this ratio as a function of the incidence $_o$ for each of the four lengths and for the same jet coefficient.

These diagrams indicate the considerable effect of fluid jets on short wings.

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LITERATURE

[1]. E. Carafoli: The influence of lateral jets, simple of combined with longitudinal jets, upon wing lifting characteristics. Proceedings of the Third International Congress of Aeronautical Sciences (ICAS), Stockholm 1962.

[2] W. Morchen: Slit losses between wings and terminal plates with and without jets in the direction of the span. Dissertation, Darmstadt 1965.

[3] N. Camarasescu: Visualisation of lateral fluid jets. Revue Roumaine Sciences Techniques Mec. Appl., 11, 2 (1966).

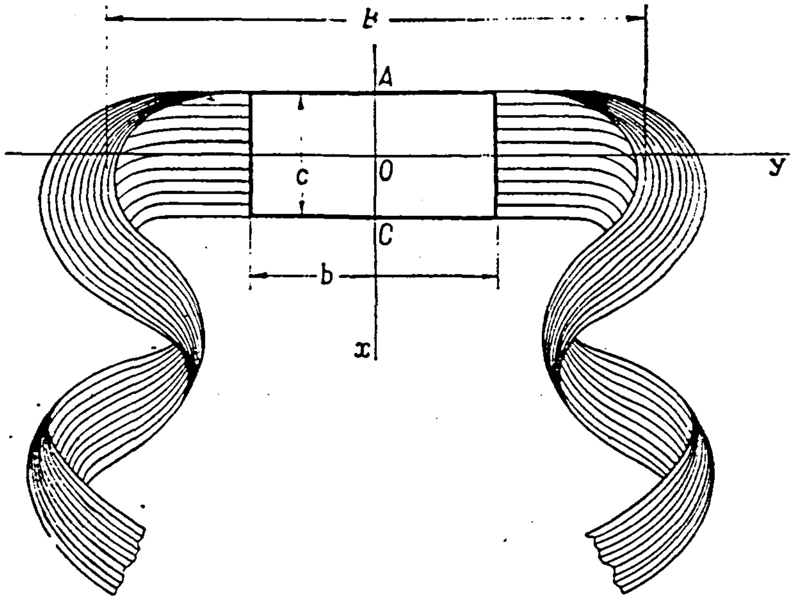


Fig. 1

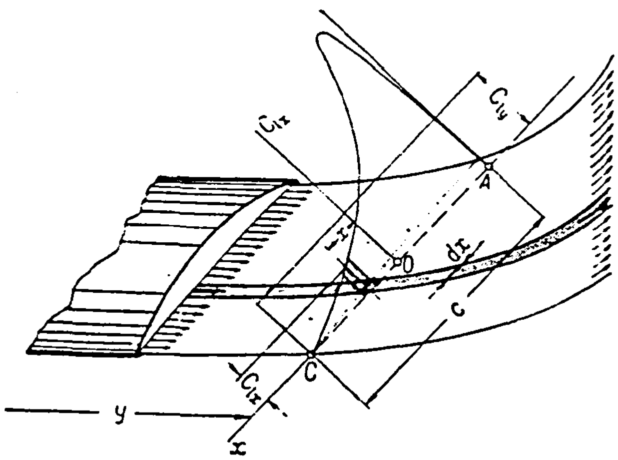


Fig. 2

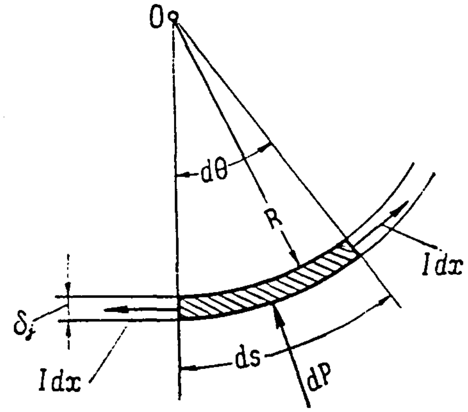


Fig. 3

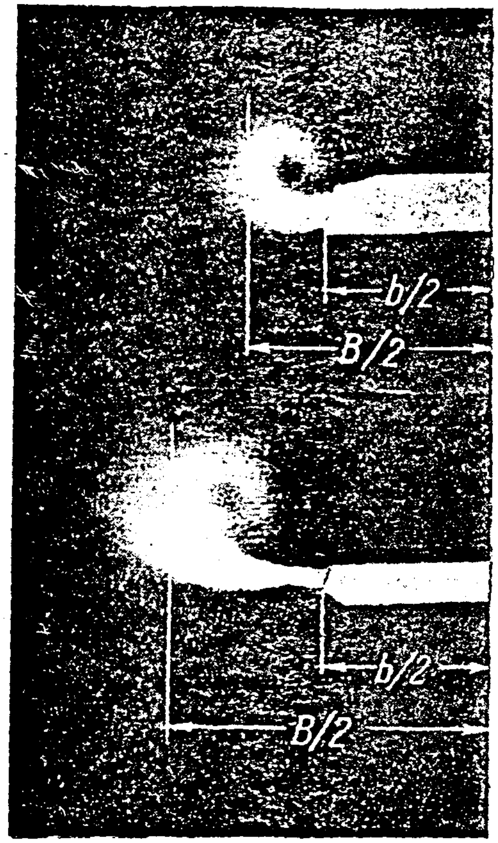

Coeficient mic de jet
Small jet co effi ci ent
b/2
B/2
Coeficient mare de jet
Large jet coefficient
b/2
B/2

Fig. 4

Fig. 5

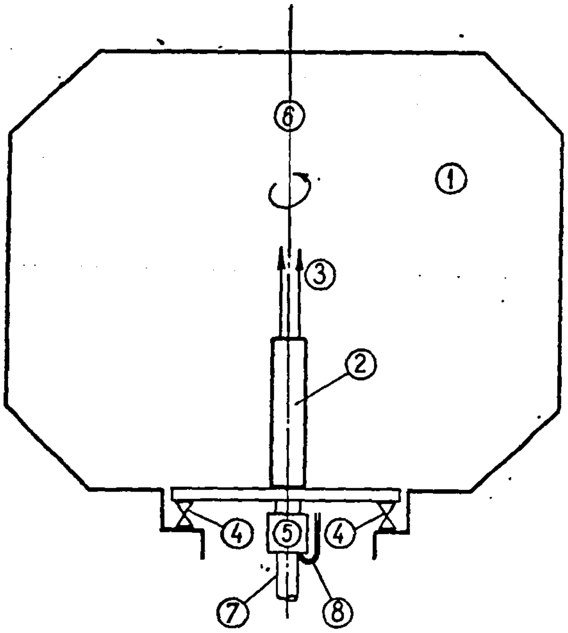
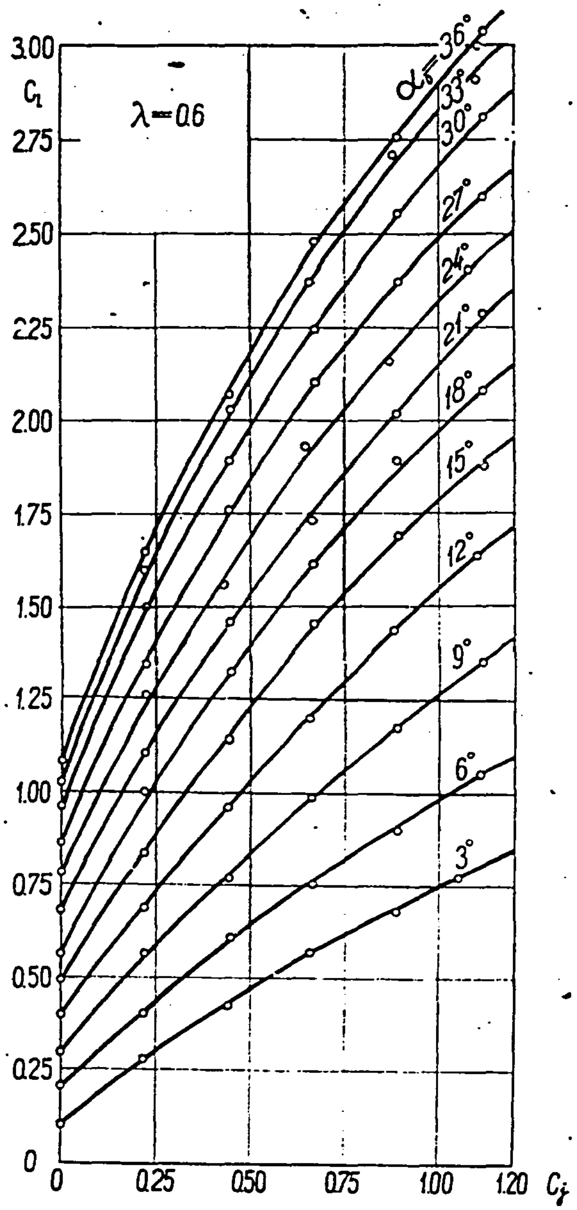


Fig. 6. — Montajul experimental:

1—camera de experienţă; 2—aripă; 3 — jet; 4 — balanţă tensometrică; 5—cuplaj elastic; 6—ax de rotaţie; 7 — conductă de alimentare cu aer de la compresor; 8—manometru cu mercur.

Figure 6

1 - experimental chamber
2 - wing
3 - jet
4 - tensiometric balance
5 - elastic coupling
6 - axis of rotation
7 - air supply duct
    from the compressor
8 - mercury manometer



C_l
$\lambda = 0.6$
$\alpha_f = 36°$
33°
30°
27°
24°
21°
18°
15°
12°
9°
6°
3°
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0
0.25
0.50
0.75
1.00
1.20
C_j

Fig. 7

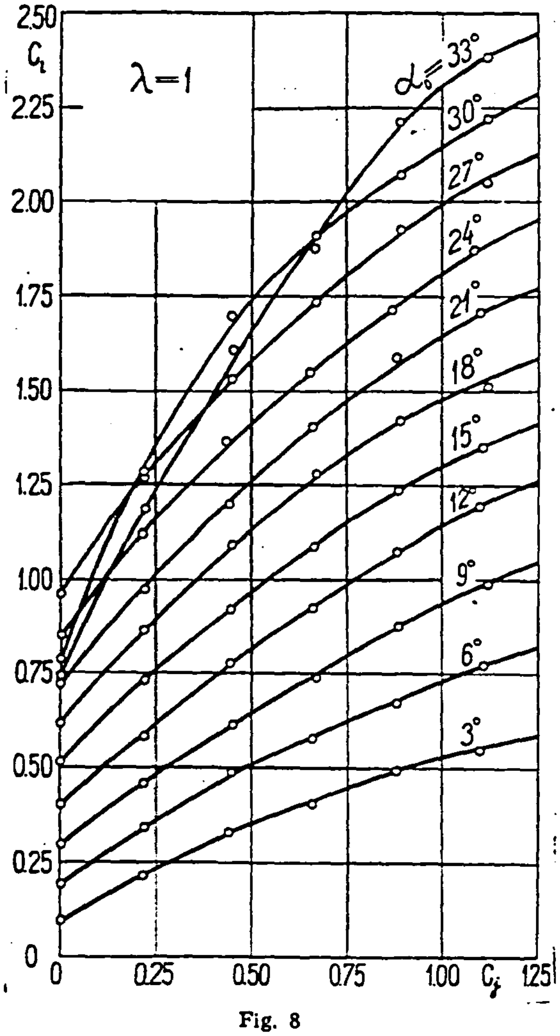

C_l
$\lambda=1$
$\alpha_0 = 33°$
30°
27°
24°
21°
18°
15°
12°
9°
6°
3°
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0
0.25
0.50
0.75
1.00
C_j
1.25

Fig. 8

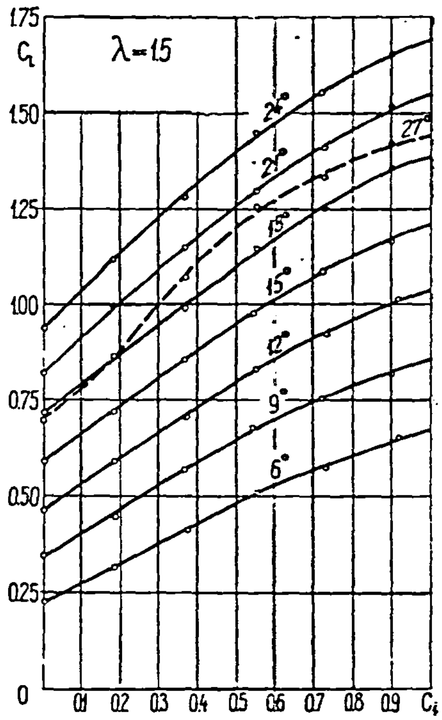

C_l
$\lambda=1.5$
24°
27°
21°
18°
15°
12°
9°
6°
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
C_j

Fig. 9

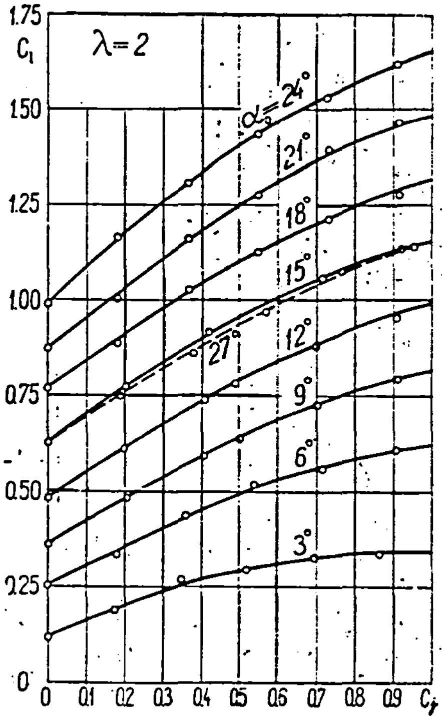

λ=2
α=24°
21°
18°
15°
12°
9°
6°
3°
27°
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Fig. 10

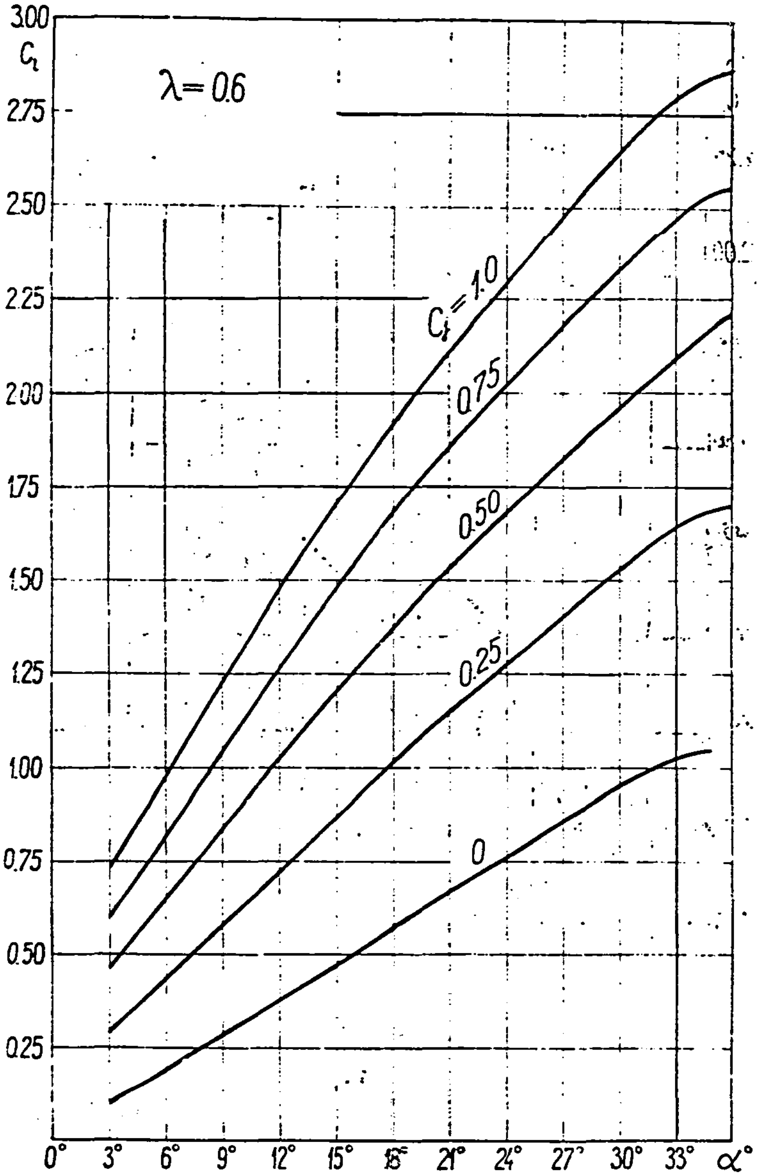

λ=0.6
1.0
0.75
0.50
0.25
0
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0°
3°
6°
9°
12°
15°
21°
24°
27°
30°
33°
α°

Fig. 11

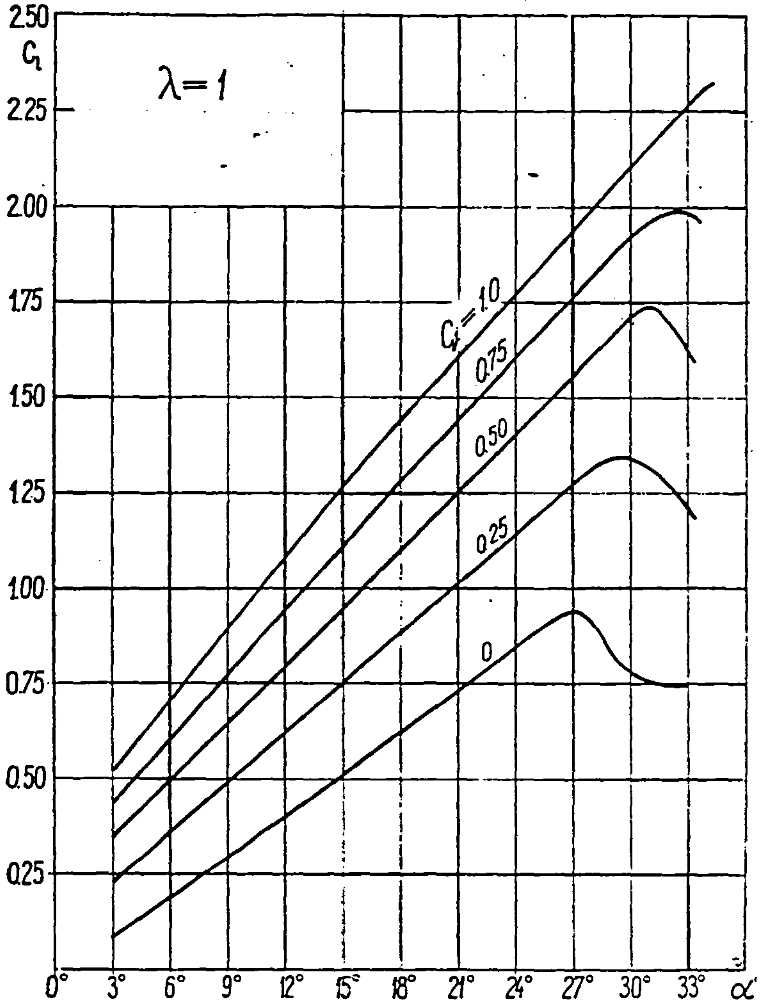

2.50
C_l
$\lambda = 1$
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
$C_i = 1.0$
0.75
0.50
0.25
0
0°
3°
6°
9°
12°
15°
18°
21°
24°
27°
30°
33°
α

Fig. 12

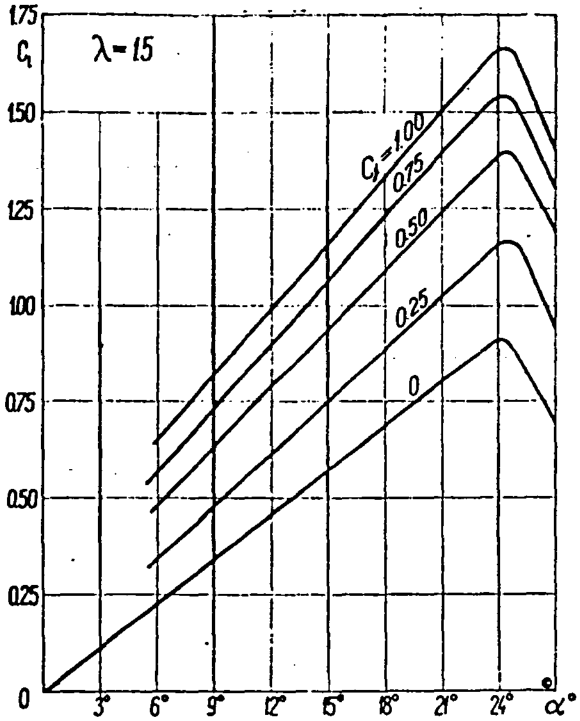


Fig. 13

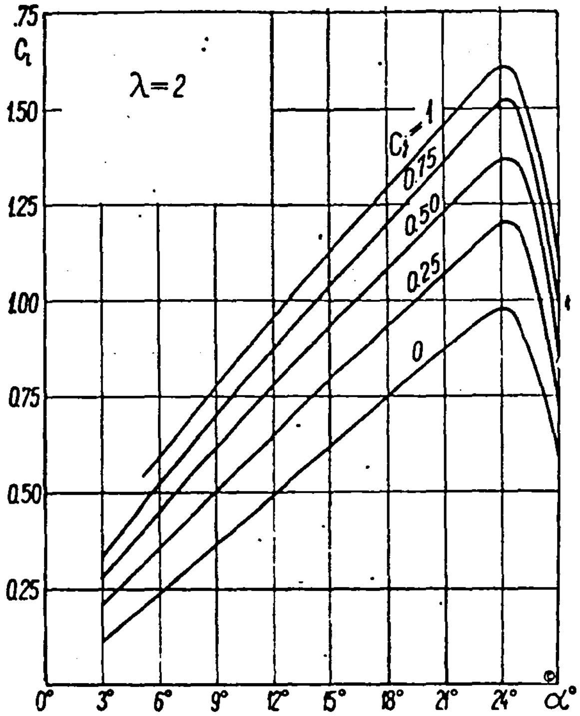


Fig. 14

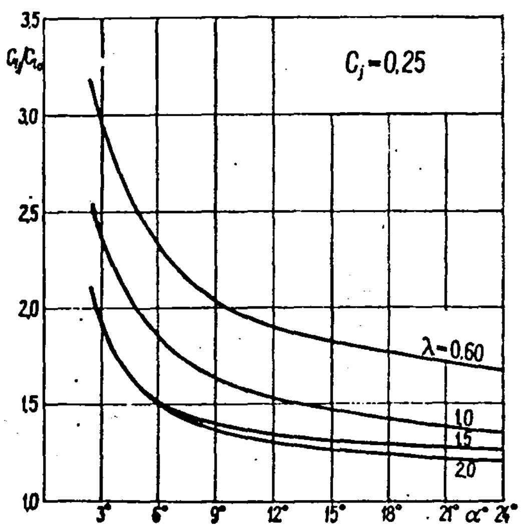


Fig. 15

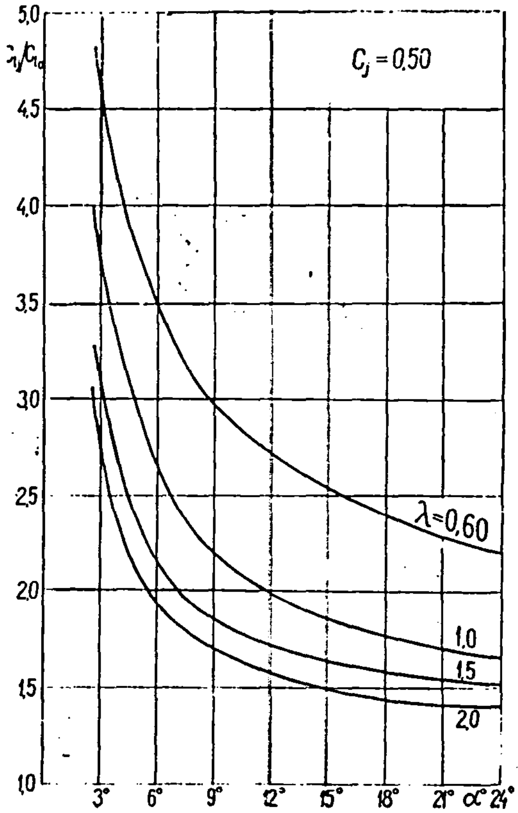
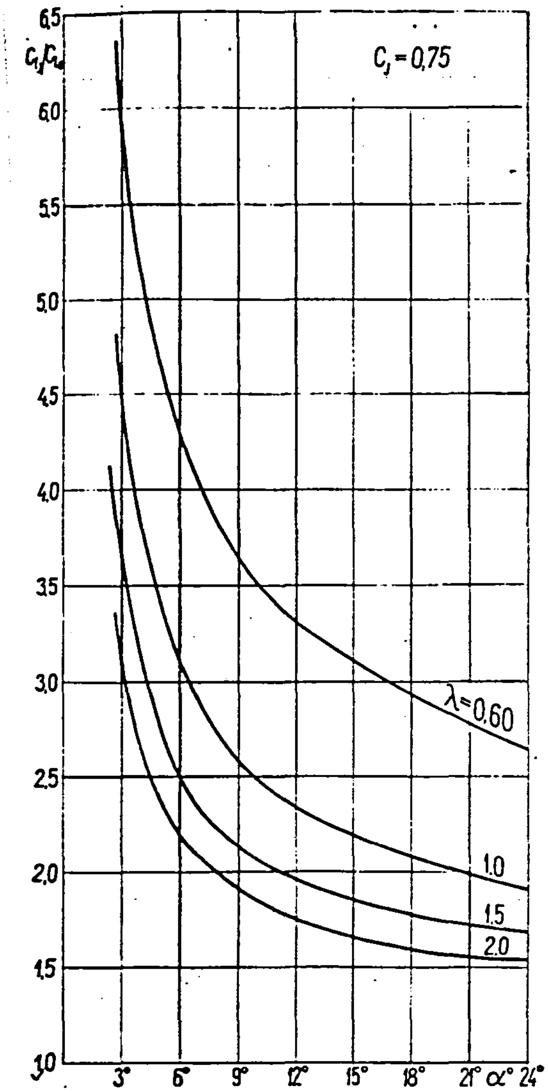
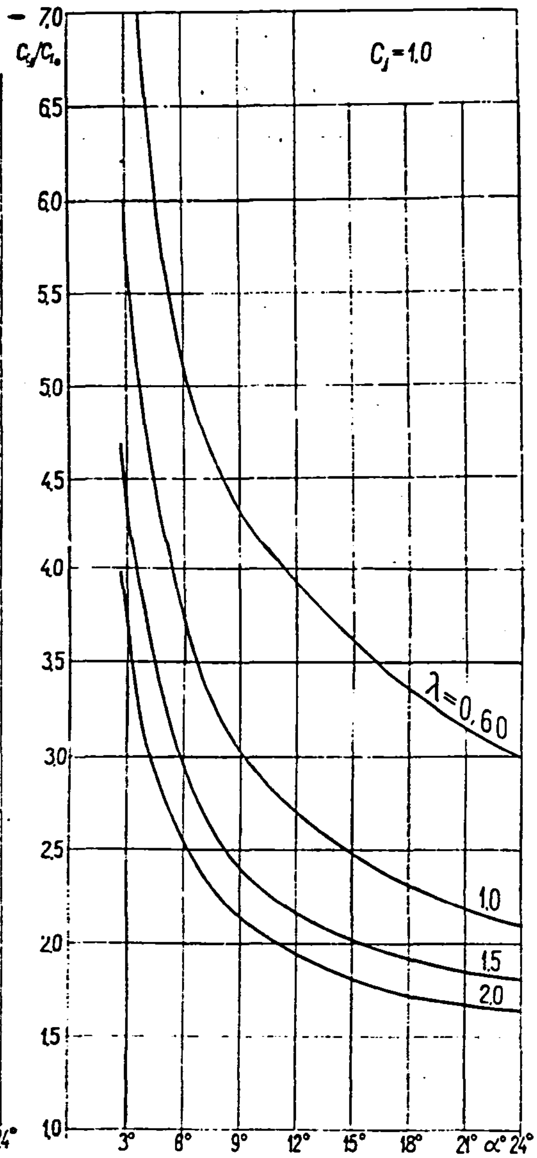


Fig. 16


C_l/C_{l_0}
$C_j = 0{,}75$
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
$\lambda = 0{,}60$
1,0
1,5
2,0
3°
6°
9°
12°
15°
18°
21°
α°
24°
Fig. 17


C_l/C_{l_0}
$C_j = 1{,}0$
7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
$\lambda = 0{,}60$
1,0
1,5
2,0
3°
6°
9°
12°
15°
18°
21°
α°
24°
Fig. 18

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